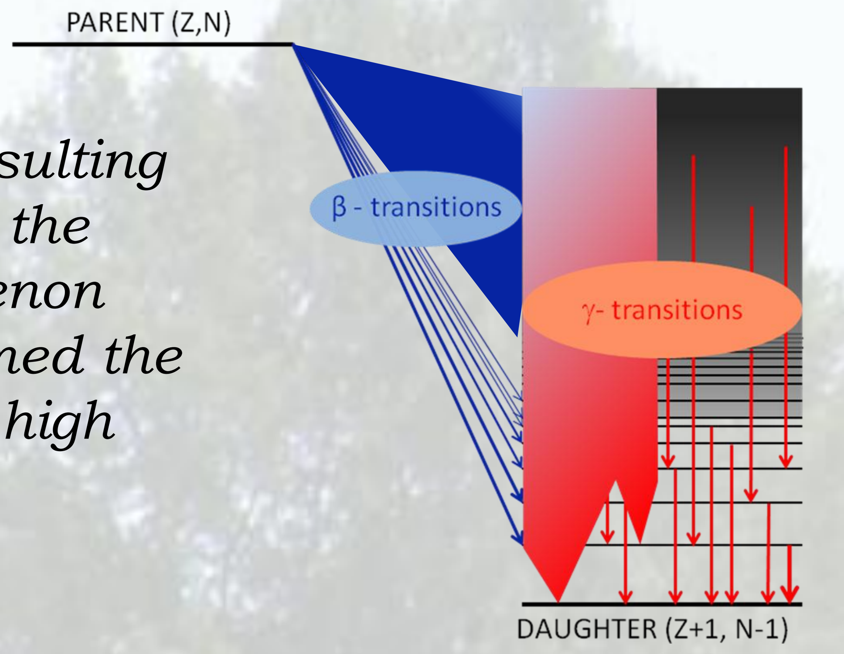
Modular Total Absorption Spectrometer at the HRIBF on line test facility (ORNL, Oak Ridge)

M.Wolińska-Cichocka (ORNL/ORAU), K.P.Rykaczewski (ORNL), M.Karny (ORNL/ORAU/Warsaw), A.Fijałkowska (Warsaw/UTK), B.C.Rasco (LSU), R.K.Grzywacz (UTK/ORNL), D.Miller (UTK), C.J.Gross (ORNL), J.Johnson (ORNL), E.Zganjar (LSU)

Why Total Absorption Gamma Spectroscopy ?

The true decay of almost any heavy neutron-rich nucleus (N,Z) contains many weak β-transitions and subsequent γ de-excitations and is sketched in figure 1. By not detecting these weak γ-transitions, the resulting "apparent" γ intensity balance in the decay of a neutron-rich nucleus artificially enhances the β-feeding to the low-energy states that are, in reality, populated by several unobserved gamma transitions. This phenomenon was analyzed by J.C. Hardy and collaborators in 1977 [Hardy et al, Phys. Lett. B71, 307, 1977], and named the "Pandemonium Effect". High-efficiency total absorption spectroscopy is capable of detecting these weak, high energy γ-transitions and establish the true decay pattern.



K.P.Rykaczewski, Viewpoint in Physics, 3, 94, 2010

Fig. 1 The illustration of "Pandemonium Effect"

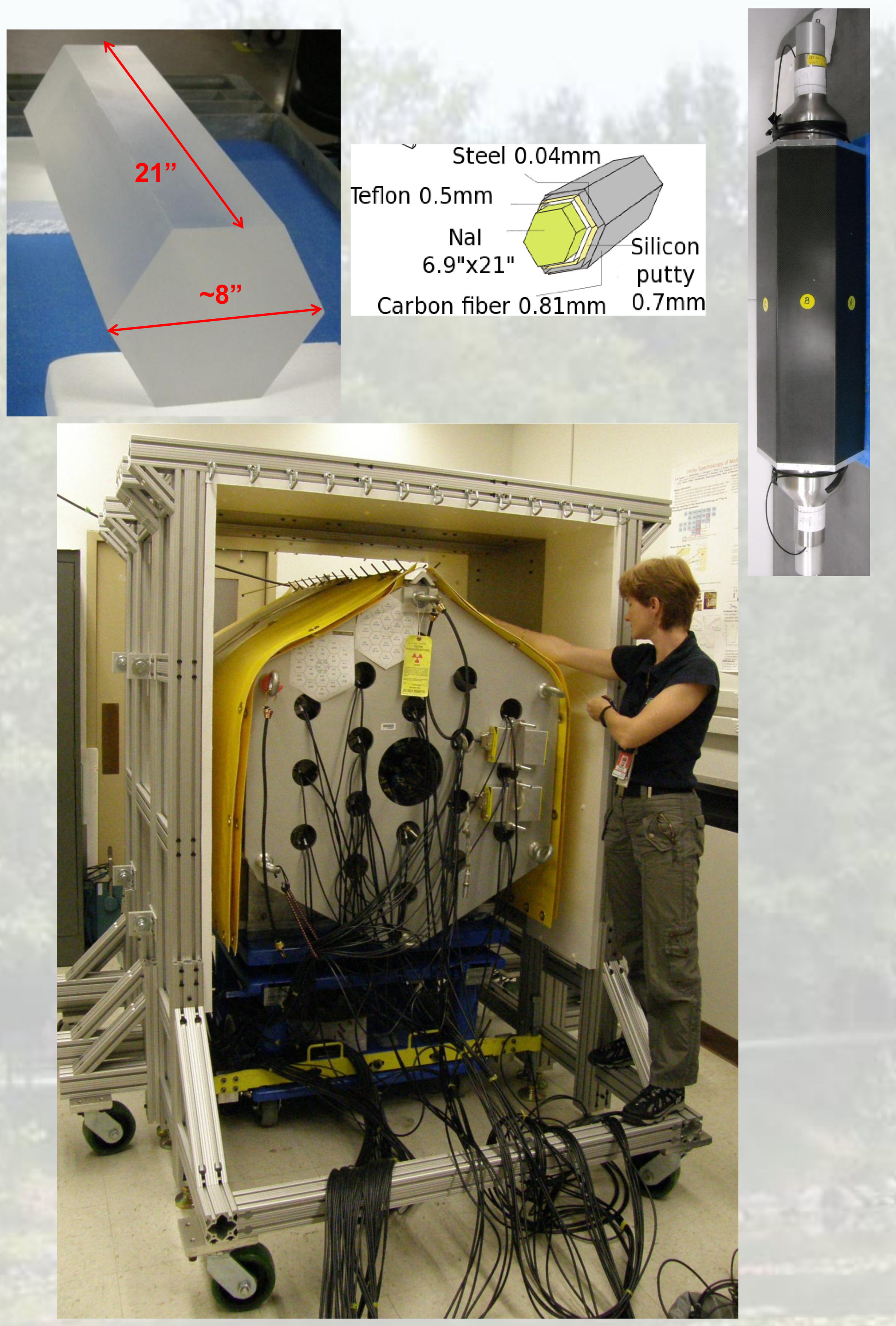


Fig.2 The HRIBF Modular Total Absorption Spectrometer (MTAS) and a part of its lead shielding

The Modular Total Absorption Spectrometer (MTAS) was commissioned at the Holifield Radioactive Ion Beam Facility (HRIBF) at Oak Ridge National Laboratory. The detector array (Fig. 2) consists of 19 NaI(Tl) hexagonal shape blocks, each 21" long and about 8" maximum diameter .

The true β-feeding pattern and resulting β strength function for neutron-rich nuclei can be derived from the total absorption γ spectrum measured with MTAS.

These studies are particularly important for the evaluation of decay heat released by fission products produced in nuclear fuels in power reactors.

MTAS has 7 times larger volume in comparison to the largest TAS previously built at LBNL and operated at GSI Darmstadt. The photo-peak efficiency of any TAS is a critical parameter for the de-convolution (understanding) of the spectra. In order to maximize efficiency in a modular design the material between crystals must be minimized. The ~2 mm layer of materials around MTAS NaI(Tl) crystals include teflon tape, silicon putty filling, a very thin layer of stainless steel and finally a carbon fiber housing (Fig.2). The total weight of the detector array is ~2200 pounds. The weight of MTAS Pb shielding is around 10000 pounds and about 4.5 cm thick.

The MTAS efficiency for full γ-energy absorption approaches 93% around 300 keV and is about 78% for a 5 MeV single γ-transition (Fig.3). The energy resolution of individual MTAS modules is below 6% at 1.33 MeV and about 7% to 8% at 0.66 MeV.

The auxiliary counters include two Si-strip detectors measuring β-energy loss signals (Fig.4).

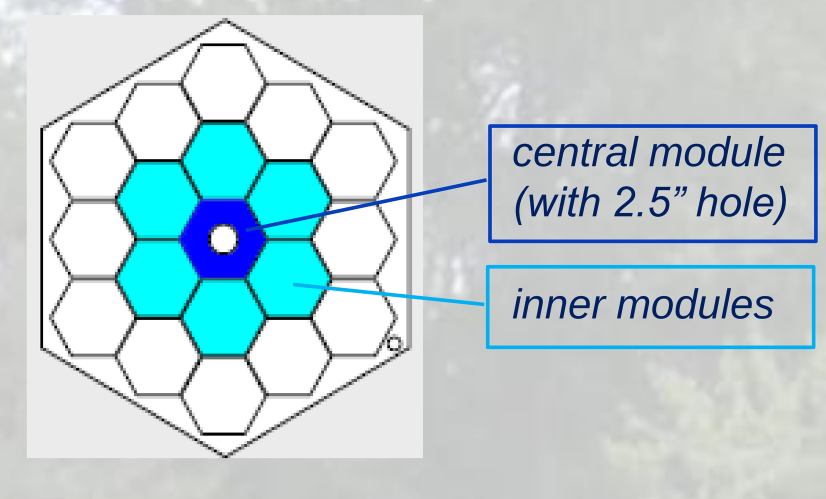
MTAS measurements of the decay heat released from neutron-rich nuclei started at the HRIBF in January 2012. These nuclei were produced by bombarding a ^{238}U target with 40 MeV protons from the HRIBF Tandem accelerator to induce fission.

The Isotope Separator On-Line technique was used to form a mass separated beam of fission fragments.

The decay of over twenty fission products including seven of the highest priority isotopes defined by the Nuclear Energy Agency in its 2007 decay heat assessment have been measured (Fig.5).

An example of the HRIBF data is given in figure 6 for ^{139}Xe decay (NEA prioritiy "1"). The measured MTAS energy spectrum (red), is compared to the simulation of the MTAS response (white) using the decay scheme of ^{139}Xe (Q_β =5057(4) keV) adopted in the Evaluated Nuclear Structure Data Files.

The comparison shows clearly an excess of high-energy release through γ-radiation observed in experiment.



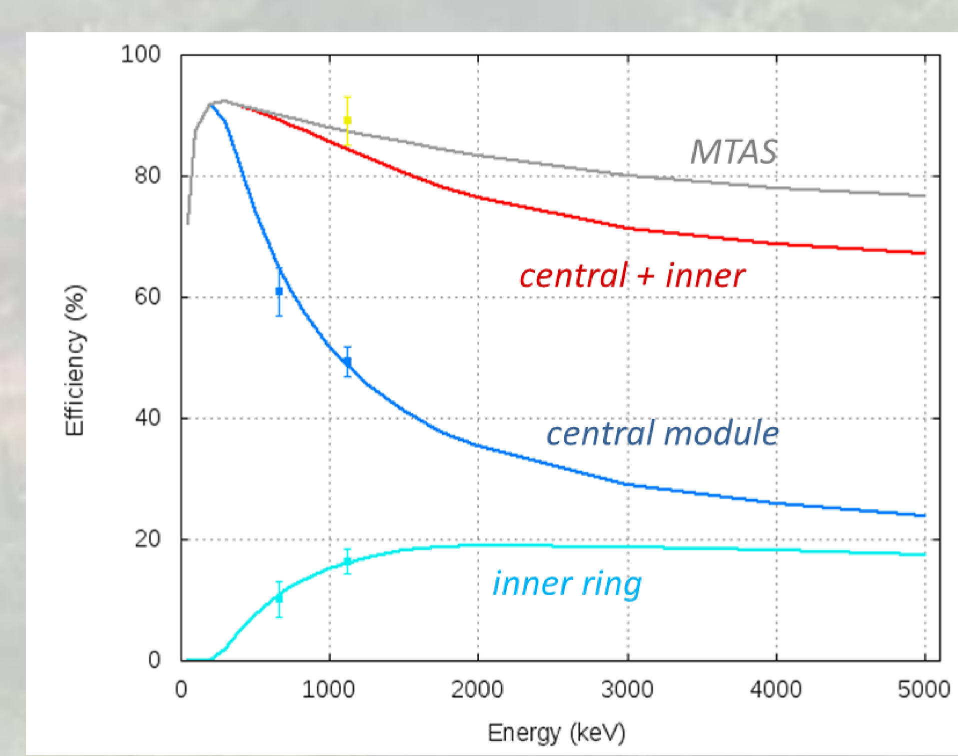


Fig.3 The test of MTAS full energy γ-efficiency with calibrated ^{137}Cs and ^{65}Zn single γ- line sources (grey – MTAS full energy peak, red –full energy peak in central and inner modules, blue – full energy peak in central module, light blue – full energy peak in inner modules

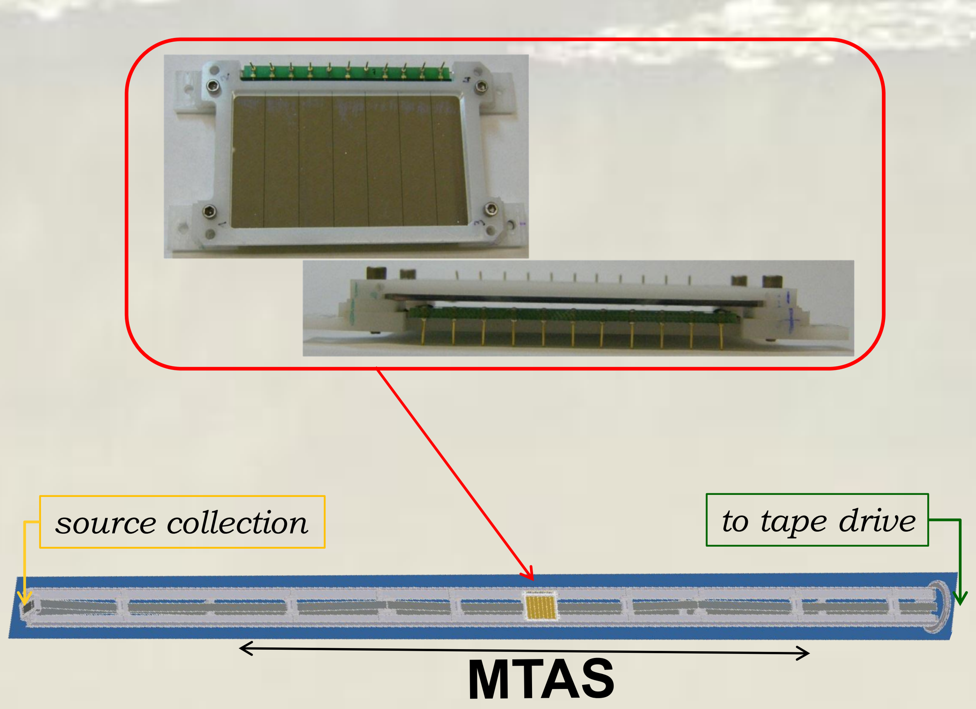


Fig.4 Segmented β- detectors and MTAS tape guide

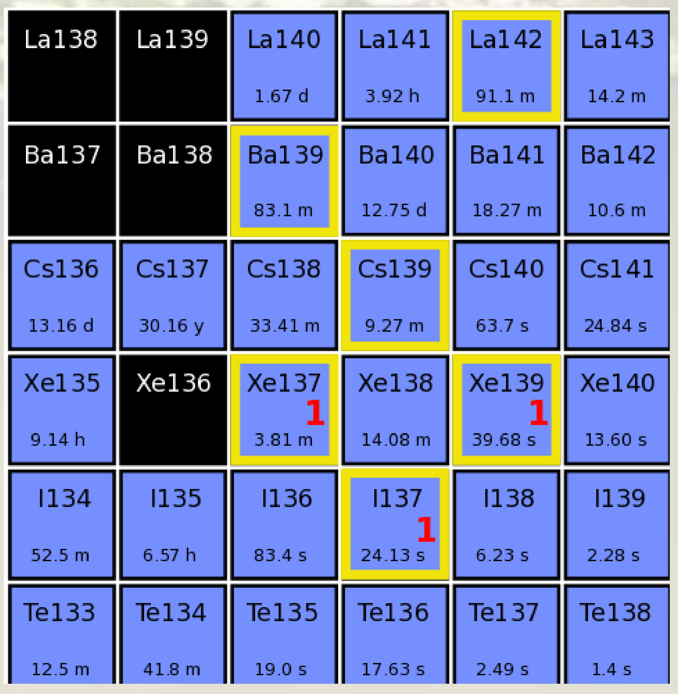


Fig.5 The β decay of fission products in the mass A~90 and A~ 140 regions studied with MTAS at the HRIBF (ORNL) are marked by yellow squares. The marking "1" and "2" indicates the priority for decay heat measurement established by the OECD NEA assessment in 2007.

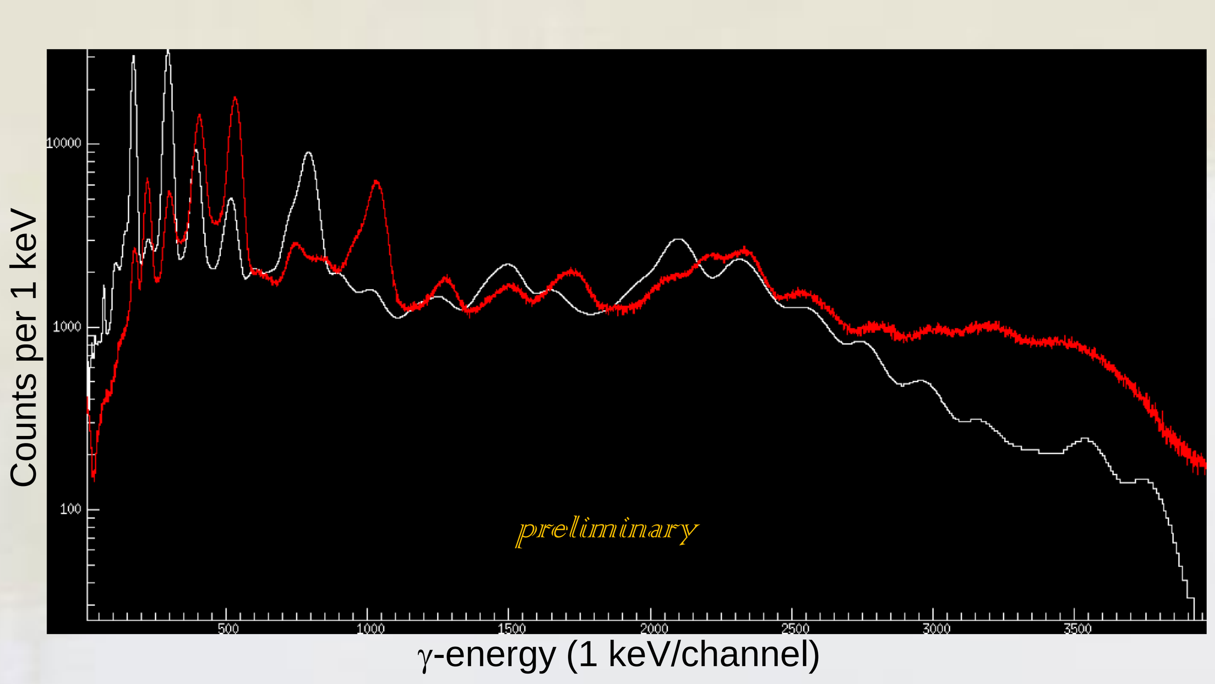


Fig.6 The measured MTAS energy spectrum (red), is compared to the simulation of the MTAS response (white) to the decay of ^{139}Xe→ ^{139}Cs. Spectra were normalized to the total number of counts.
[A. Fijałkowska et al., private comm., 2012]